DESCRIPTION OF THE AQUATIC LARVA AND PUPA OF *PARALICHAS TRIVITTIS* (COLEOPTERA: PTILODACTYLIDAE), WITH NOTES ON ITS BIOLOGY[1]

David H. Funk[2], Heidi Fenstermacher[3]

ABSTRACT: The larva and pupa of *Paralichas trivittis* (Germar) (Ptilodactylidae: Cladotominae) are described and illustrated from spring seeps in Pennsylvania, USA. Larvae can be distinguished from all other known North American beetles by the presence of a highly modified 8th abdominal segment that is tapered posteriorly to form a spiracular siphon. Larvae were found in organic muck from woodland spring seeps and appeared to be detritivores. Densities of up to 1400 larvae per square meter were observed. Pupation occurred near the larval habitat. Adults were found from June 6 to July 11. Notes on mating behavior, oviposition, egg development and faunal associations are provided.

While studying aquatic fauna in woodland spring seeps in southeastern Pennsylvania (Fenstermacher 2002), we found distinctive beetle larvae that were unidentifiable using existing taxonomic keys (e.g., Lawrence 1991, White and Brigham 1996). Laboratory rearings established that the larva was that of *Paralichas* (=*Odontonyx*) *trivittis* (Germar). In this paper we describe and illustrate the larva and pupa, as well as provide notes on their biology.

The family Ptilodactylidae occurs worldwide and contains about 40 genera and 450 species (Lawrence 1991). Fifteen species from 6 genera occur in the Nearctic. Of those, larvae of *Anchytarsus* (1 sp.) and *Anchycteis* (1 sp.) are known to be aquatic, *Araeopidius* (1 sp.) are semi-aquatic and *Ptilodactyla* (9 spp.) are terrestrial. Larvae of *Lachnodactyla* (2 spp.) and *Paralichas* (1 sp.) are unknown.

Paralichas trivittis (Germar)

Germar (1824) described the adult as *Dasytes trivittis*. Guérin-Méneville (1843) erected *Odontonyx* and later (Guérin-Méneville 1849) transferred *Atopa ornata* Melsheimer (1845) to it. Lacordaire (1857) synonymized *O. ornata* and *D. trivittis*. Stribling (1986) included *Odontonyx* in *Paralichas* White (1859). Lawrence and Newton (1995) formalized this synonymy. Stribling (1986) listed 10 valid *Paralichas* species (7 Asian, one from Madagascar, one with locality unknown and one [*trivittis*] from eastern North America) and two undescribed Neotropical species.

Adult *Paralichas* can be distinguished from all other ptilodactylids by the presence of pectinate ungues. Guérin-Méneville (1849) provided figures of the adult, including a color habitus. We illustrate the adult male in Figure 9.

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[2] Stroud Water Research Center, 970 Spencer Road, Avondale, Pennsylvania 19311.

[3] Department of Entomology and Applied Ecology, University of Delaware, Newark, Delaware 19717-1303.

Larva

(Figures 1-5, 10)

Length from 1.2 mm (first instar) to 25 mm. Body elongate, subcylindrical; heavily sclerotized and pigmented; color mostly reddish brown, cuticle between dorsal sclerites paler, with one median and two pairs of lateral dark maculae that, taken together, give the appearance of 5 broken, longitudinal stripes extending from behind the head to the base of the 8th abdominal segment; surfaces mostly microscopically tuberculate; vestiture mostly feather-like setae (Fig.10) which appear as scales under lower magnification, with some simpler setae.

Head: Prognathous, depressed, subquadrate; about as long as wide, with sides roughly parallel. Posterior edge of head capsule emarginate. Epicranial stem absent; frontal arms U-shaped. Stemmata present in a single cluster. Antennae short, three-segmented, length about 0.38 times head width; sensorium about as long as segment 3. Frontoclypeal suture indistinct. Labrum transverse, completely separated from frontoclypeus; length about 0.3 times width; not emarginate anteriorly; base partially concealed by granulate membrane. Ventral epicranial ridge present, encasing maxillolabial complex. Mandibles stout, wedge-like, symmetrical; apex tridentate; incisor area concave between dorsal and ventral carinae, with dense brush in concavity and a single, weak tooth on dorsal carina; without mola; no mesal articulated process. Maxillolabial complex retracted; cardines well separated; stipites free; maxillary articulating area well developed, concealed by lateral expansion of mentum; galea and lacinia 1-segmented, articulated, setose; maxillary palp 4-segmented. Labium with prementum, mentum and submentum; ligula with apical margin straight; labial palps widely separated, 2-segmented, with well-developed palpiger; mentum large, expanded laterally, not divided longitudinally; submentum sclerotized and distinct anteriorly, indistinct posteriorly. Gular sutures indistinct. Hypopharynx simple.

Thorax: Prothorax about 1.6 times as long as mesothorax, which is subequal to metathorax. Terga large, extending to lateral edge of venter. Protergum with narrow anterior and posterior areas lightly sclerotized, finely granulate and reticulate, with scattered finely branched setae; central area heavily sclerotized, largely covered with palmately feathered setae (that appear as scales under lower magnification), each with a round tubercle arising near its base, and with a distinctive pattern of small, smooth areas; meso- and metatergum with similar vestiture, fewer markings; abdominal terga similar, markings fewer still. Mesothoracic spiracle located on anterior third of tergum about halfway between dorsal and ventral extremities; small, biforous. Metathoracic spiracle rudimentary, apparently non-functional. Presternal area of prothorax consisting of an anterior rectangular sclerite with three regions of heavier sclerotization: a narrow median area and broader lateral areas; two triangular sclerites posteriorly, their apices meeting at the midline. Basisternum transverse, protuberant medially, well separated from transverse sternellum. Mesothorax with basisternum in two parts: anterior part transverse, meeting posterior edge of prothoracic sternellum, with a low, blunt tubercle medially and lower projections laterally; posterior portion (precoxalia?) transverse with sharp median tubercle and fused with episternum laterally, which bears a sharp tubercle at anterior base of coxa; epimeron crescent-shaped behind pleural suture; sternellum narrow, transverse; coxae well separated and postcoxalia not sclerotized. Ventral portion of metathorax similar in structure. Leg armed with stout setae, coxa with longer, finer setae in addition; approximate ratio of segment lengths: 2.7: 2: 1.4: 1: 1; tarsungulus with a single, weak, feeble seta, often missing.

Abdomen: Segments 1-7 of same general structure as thorax; segment 1 slightly shorter than 2-7, which are subequal; tergum slightly more extensive than on thorax; pleurites present on 1-7; sternal area on 1-6 with a median triangular sclerite, acute posteriorly, with a linear sclerite on either side; segment 7 similar but sternite truncate posteriorly, without linear sclerites laterally. Spiracle similar in structure and location to that on mesothorax. Vestiture and pattern of smooth areas generally similar to that of thorax. Cuticle between dorsal sclerites with one median and two pairs of lateral dark spots that, when taken together, give the effect of 5 broken, longitudinal stripes extending from behind the head to the base of segment 8. Ecdysal line extending only as far as segment 7.

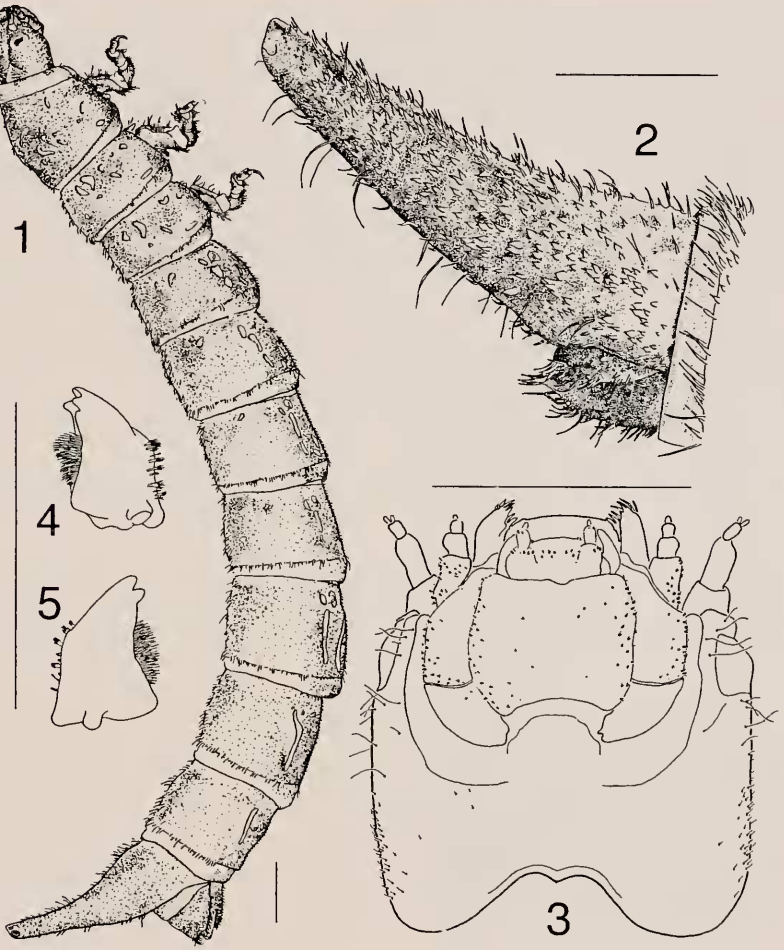

Figure 1-5. *Paralichas trivittis*, larva. 1. Full-grown larva, lateral. 2. Spiracular siphon (abdominal segment 8) and operculum (segment 9-10). 3. head, ventral. 4. Right mandible, dorsal. 5. Right mandible, ventral. Line = 1.0 mm.

Segment 8 highly modified, without sternum, longer than preceding segments, tapered posteriorly into a long, slightly upturned siphon with large spiracles at its apex. Segment 9 attached ventrally to 8, reduced to an incomplete band, without urogomphi; segment 10 with a flattened plate forming a hinged operculum. Gills, hooks and osmoregulatory organs absent.

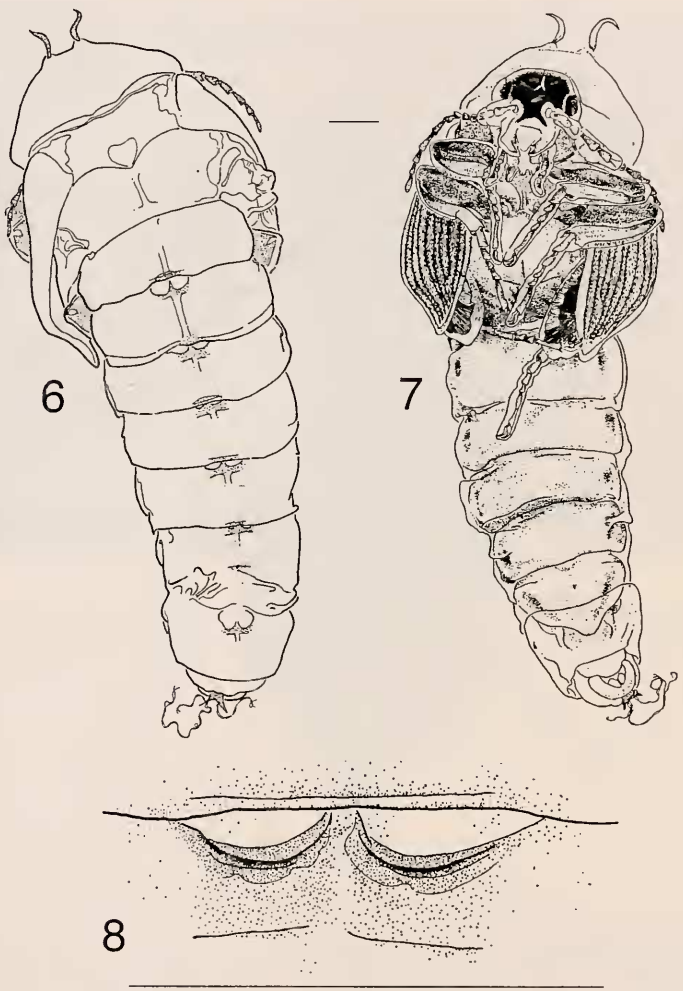

Figure 6-8. *Paralichas trivittis*, pupa. 6. dorsal. 7. ventral. 8. Gin-trap on segment 4-5. Scale = .0 mm.

Pupa

(Figures 6-8)

Length 14-16 mm. Color pale (cuticle translucent), with pronotal styli, spiracles, gin-traps and cerci testaceous.

Head: Smooth, with scattered, mostly bifurcate, setae visible at higher magnifications (>100X). Antennae directed posteriorly. Maxillary and labial palpi extended posteroventrally.

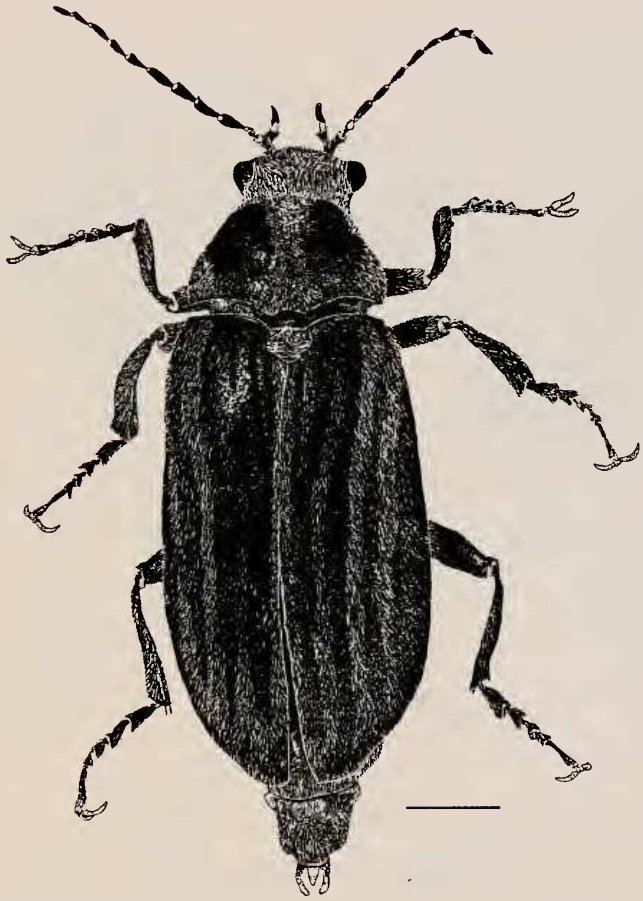

Figure 9. *Paralichas trivittis*, male imago, dorsal. Scale = 1.0 mm.

Thorax: Smooth, with a few scattered setae visible at higher magnifications (>100X). Pronotum with 2 large styli arising from broadly rounded tubercles near anterior margin; slightly sigmoid in shape with dense, hydrofuge spination. Wingpads tucked ventrally, lying between meso- and metathoracic legs. Each leg with femora extending outward at right angle to body axis; tibia folded against femur; tarsi extending posteriorly along body axis.

Abdomen: Appearing smooth under low (<100X) magnification; at higher magnifications scattered, branched setae evident, with fine, dense patches of spines ("shagreen") appearing as irregular bands extending laterally from gin-traps near anterior margins of tergites; intersegmental cuticle granulate. Spiracles present on segments 1 to 7. Gin-traps, 6; present between first through seventh abdominal segments; consisting of a single, lightly sclerotized carina on posterior margin of segments 1 to 6, opposing a pair of heavily sclerotized, crescent-shaped carinae on anterior margin of segments 2 to 7. Urogomphi short, sclerotized, acuminate, divergent.

Figure 10. *Paralichas trivittis*, photomicrograph of scale-like setae on abdominal tergum 2. Setae arise from the base of a low, rounded tubercle. Scale = 100 microns.

Specimens examined.

115 from benthic samples collected between June 2000 and March 2001, three spring seep tributaries of spring brook known locally as Watercress Spring, East Branch White Clay Creek, Chester Co., Pennsylvania, USA (locations of seeps: 39°52'28.0"N, 75°47'24.5"W; 39°52'27.5"N, 75°47'25.8"W; 39°52'27.3"N, 75°47'26.4"W; all approximately 113 m elevation); 1 collected from Ledyard's Spring Brook (39°52'44"N, 75°47'29"W, elevation 119 m), 1972.xii.11. Material deposited at Stroud Water Research Center, Academy of Natural Sciences of Philadelphia and the U. S. National Museum of Natural History.

Pupae: 1 intact, 3 exuviae from laboratory rearing tray on 2001.vi.15 (from larvae collected 2000.viii.22, Watercress Spring, 39°52'27.5"N, 75°47'25.8"W). Material deposited at the Stroud Water Research Center and the Academy of Natural Sciences of Philadelphia.

Imagines: 2 males, 5 females from laboratory rearing tray 2001.v.23 – 2001.vi.15, from larvae collected 2000.viii.22, Watercress Spring, 39°52'27.5"N, 75°47'25.8"W; 30 males, 1 female, from malaise trap, same locality, 2001.vi.13 – 2001.vii.11; 4 males, 2 females, malaise trap, Sawmill Spring, 39°51'54"N, 75°46'54"W, 1984.vi.26 – 1984.vii.12. Material deposited at the Stroud Water Research Center.

Discussion

The presence of an elongate spiracular siphon on abdominal segment 8 (Figs. 1 and 2) with operculate segment 9 attached ventrally will distinguish the larvae of *Paralichas* from all other known North American beetle genera.

Hayashi (1986) illustrated the larva of *Paralichas pectinata* (Kiesenwetter) from Japan and Costa et al. (1999) provided a description and detailed illus-

trations for that species. We have not examined *P. pectinata*, but from the illustrations provided by Costa, et al. (1999) it would appear that *P. trivittis* and *P. pectinata* are quite similar. The only other cladotomine larva known at present is that of *Austrolichas monteithi* (Lawrence and Stribling 1992). *Austrolichas* larvae also have a spiracular siphon on segment 8 and a reduction and ventral placement of segment 9 with an operculum. Lawrence and Stribling (1992) reported seeing an unassociated larva from Venezuela which appeared to be of the same type as *Paralichas* and suggested it might represent *Cladotoma* Westwood. We have seen larvae collected from tree holes in Panama that are similar to *Paralichas* in most respects, including the spiracular siphon, which may represent *Octoglossa* (P. J. Spangler and W. E. Steiner, Jr., personal communication). It seems likely that the spiracular siphon on segment 8 is present in all Cladotominae, and possibly other ptilodactylids (e.g., *Octoglossa*).

Paralichas larvae will not key in current editions of White and Brigham (1996) or Stehr (1991). In White and Brigham's (1996) family key *Paralichas* larvae will end up at Dryopidae (couplet 26). However, couplet 24 (segment 9 with or without an operculum) is rather ambiguous with regard to *Paralichas* larvae, in which segment 9 itself appears to form an operculum beneath segment 8. The insertion of a new couplet prior to existing number 24 would allow the easy separation of *Paralichas* larvae:

24a(23)	Abdominal segment 8 highly modified, without sternum, longer than preceding segments, tapered posteriorly into a long, slightly upturned siphon with large spiracles at its apex	Ptilodactylidae (in part)
24a'	Abdominal segment 8 similar in structure to segment 7	24

A similar couplet at the beginning of the ptilodactylid larval key would separate *Paralichas* from the remaining genera. Adult *Paralichas* can be distinguished from all other ptilodactylids by the presence of pectinate ungues.

In Lawrence's (1991) key to Coleoptera larvae, *Paralichas* will dead end at couplet 191 (Dryopidae and Chelonariidae); well separated cardines and biforous spiracles would take it to Dryopidae, but cuticular surface structure and vestiture would indicate Chelonariidae. Again, the insertion of a couplet such as the one above would separate *Paralichas* easily.

Biology

Habitat Description and Rearing Methods

Paralichas trivittis larvae were found in spring seep habitats in southeastern Pennsylvania. Seep habitats in this area are typically 2-5 m wide and shallow with substrates dominated by sand and fine quartzite gravel overlain with mud, fine particulate matter and mixed detritus (i.e., an organic muck). The dominant vegetation type within these seeps consists of herbaceous plants such as skunk cabbage (*Symplocarpus foetidus* [L.] Nutt.) and jewelweed (*Impatiens capensis* L.). A mixed hardwood deciduous forest surrounds the seeps and leaf litter constitutes a main component of the diet of the aquatic fauna.

Thirty-eight larvae (approximately two-thirds to full grown) collected August 22, 2000 were placed in two rearing trays constructed from standard rat trays (polypropylene, 45 cm long, 25 cm wide, 20 cm deep). Trays had screened sections in the bottom and ends to allow water flow and a screen cover with an emergence trap. Trays were filled with substrate from the spring seep to about 5 cm depth. One tray was immersed in the spring seep where the larvae were collected, and the other was placed in an artificial stream in the Stroud Water Research Center (water pumped from White Clay Creek). In December the tray positioned in the field was brought into the laboratory stream because of concerns about frost-heaving of the tray and freezing of its substrate. The first adult beetle appeared in the laboratory on May 23, 2001. Seven more adults emerged over the following two weeks. On June 15 the contents of the trays were sieved, and one pupa was collected and preserved, as well as pupal and larval exuviae from the other adults. Larvae, pupae and adults were all found in the same muck habitat. Nine larvae were returned to one of the trays and rearing in the lab continued at ambient White Clay Creek

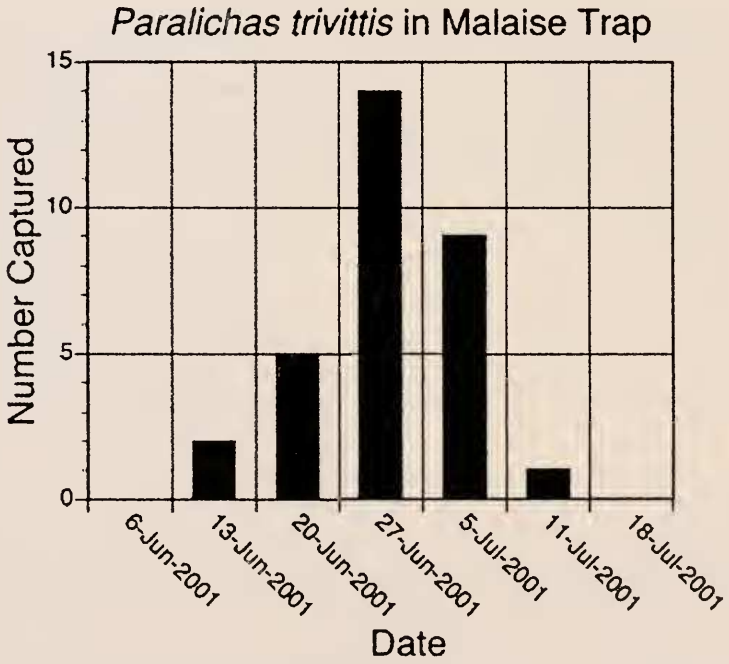

Figure 11. The appearance of *Paralichas trivittis* adults in Malaise trap collections, Watercress Spring, East Branch White Clay Creek, Chester Co., Pennsylvania, USA (39°52'27.5"N, 75°47'25.8"W), 2001.

temperatures. Between June 7 and June 24, 2002 another 5 adults (1 male, 4 female) emerged in the tray. Since the larvae appeared to be two-thirds to full grown when collected in August 2000, it seems likely that at least two years are required to complete larval development in the field.

Densities

Quantitative benthic sampling was performed at ten spring seep sites in southeastern Chester County, Pennsylvania, USA (Fenstermacher 2002). Six samples were taken at each site in June 2000, September 2000 and March 2001. Each sample was a composite of three scoops for a total of 0.06 m^2. *Paralichas trivittis* larvae were found in three of the seeps, all tributaries of Watercress Spring (see Specimens examined, above). Of the fifty-four samples taken from those three sites, 22 contained a total of 115 *P. trivittis* larvae. Density estimates ranged from 0 – 1400/m^2 with a mean of 260/m^2.

Faunal Associations

The following insect taxa were found in samples containing *P. trivittis*: **Plecoptera**: *Soyedina carolinensis* (Claassen) (Nemouridae) and *Leuctra variabilis* Hanson (Leuctridae); **Megaloptera**: *Sialis* (Sialidae) and *Nigronia fasciatus* (Walker) (Corydalidae); **Trichoptera**: *Frenesia missa* Milne (Limnephilidae), *Lepidostoma sommermanae* Ross (Lepidostomatidae), *Psilotreta rufa* (Hagen) (Odontoceridae), *Beraea* (Beraeidae), *Molanna blenda* Sibley (Molannidae), *Rhyacophila* (Rhyacophilidae), and *Phylocentropus* (Polycentropodidae); **Coleoptera**: *Agabus* and *Hydroporus* (Dytiscidae), *Cymbiodyta* and *Tropisternus* (Hydrophilidae), *Optioservus* (Elmidae), *Prionocyphon* and *Scirtes* (Scirtidae) and *Anchytarsus* (Ptilodactylidae); **Diptera**: *Atrichopogon*, *Ceratopogon* and *Probezzia* (Ceratopogonidae), Chironomidae, *Chrysops* (Tabanidae), *Hexatoma, Limnophila, Limonia, Molophilus, Ormosia, Oxycera, Pedicia, Pilaria, Pseudolimnophila,* and *Tipula* (Tipulidae), *Bittacomorpha* and *Ptychoptera* (Ptychopteridae), *Pericoma* (Psychodidae), *Dixa* (Dixidae) and *Clinocera* (Empididae).

Behavior

Paralichas larvae were collected in the field by sieving the organic muck they inhabit. Captured larvae were very slow-moving. When submersed in water, the spiracular siphon of the 8th abdominal segment was observed to protrude through the water surface. Larval gut contents consisted of amorphous organic detritus. No diatoms or animal remains were observed, indicating *P. trivittis* is a detritivore.

Pupae were found in the larval habitat, with the larval exuviae attached by means of an entanglement of the larval tracheae on the sharp, pupal urogomphi. We saw no evidence of a pupal cocoon (such as that described by White, 1859, for *Paralichas guerinii*).

Reared adult *P. trivittis* were maintained in the laboratory for up to three weeks in Petri dishes provisioned with a small wad of tissue (Kimwipes®) kept moist with water (to maintain humidity) and sugar water. Two males were observed drumming with their mesothoracic legs. Each drumming phrase consisted of a left-right alternating, rapidly accelerating pattern of about 10-20 beats that lasted about a second. On two occasions receptive females were observed to answer male drumming bouts in what appeared to be an identical phrase commencing about 0.5 seconds after the male's phrase. These bouts were continued until the male located the female, whereupon he mounted. Males were observed palpating the females' heads and pronota with their antennae while attempting intromission. Once intromission was achieved, copulation continued for 2 to 4 hours. Females kept in Petri dishes laid eggs individually in the small wad of moist tissue that had been provided to maintain humidity. Hatching began 8 days after oviposition.

Seasonality of Adults

On May 30, 2001 a Malaise trap was placed at the site where *Paralichas* appeared most commonly in benthic samples (Watercress Spring; 39°52'27.5"N, 75°47"25.8"W). The trap was emptied weekly for the remainder of the calendar year. A total of 31 individuals was captured between June 6 and July 11, 2001 (Figure 11). All specimens were captured. Examination of archived Malaise collections from a nearby spring (Sawmill Spring; 39°51'54"N, 75°46'54"W, elevation 113 m) from 1984 revealed six *P. trivittis* adults (4 males, 2 females) captured between June 19 and July 12. In the laboratory, adults appeared about 2 weeks earlier, probably due to a slightly warmer thermal regime.

Of the 31 individuals captured in the Watercress Spring Malaise, 30 were males. Laboratory rearings gave no indication of a male-biased sex ratio (total = 2 male, 5 female). Both of the laboratory-reared males were found at the top of the cage, whereas three of the five females were found only when we sieved the rearing tray contents looking for pupae. This and the paucity of females captured in the Malaise suggests that males may disperse more actively than females.

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